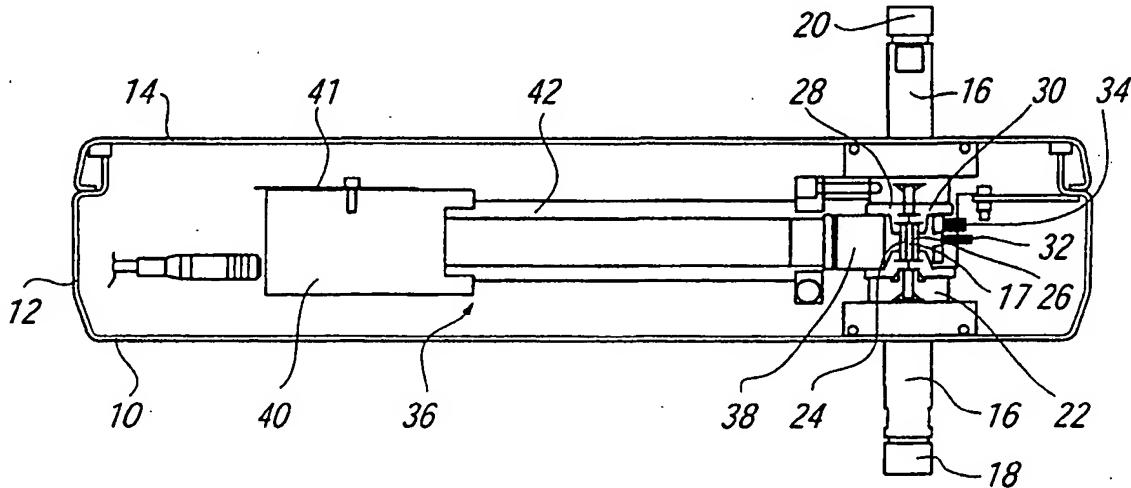




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G01N 15/14		A1	(11) International Publication Number: WO 00/46586
			(43) International Publication Date: 10 August 2000 (10.08.00)
(21) International Application Number: PCT/GB00/00336		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).	
(22) International Filing Date: 3 February 2000 (03.02.00)			
(30) Priority Data: 9902549.6 5 February 1999 (05.02.99) GB			
(71) Applicant (for all designated States except US): JORIN LIM-ITED [GB/GB]; 4a Vulcan Close, Sandhurst, Berkshire GU47 9DB (GB).			
(72) Inventors; and			
(75) Inventors/Applicants (for US only): ROTH, Nicholas, James [GB/GB]; 4a Vulcan Close, Sandhurst, Berkshire GU47 9DB (GB). ROTH, John, Robert [GB/GB]; 4a Vulcan Close, Sandhurst, Bershire GU47 9DB (GB). GASKIN, Roderick, Clive [GB/GB]; 4a Vulcan Close, Sandhurst, Berkshire GU47 9DB (GB).			
(74) Agents: CROUCH, David, John et al.; Bromhead & Co., 19 Buckingham Street, London WC2N 6EF (GB).			

(54) Title: APPARATUS FOR AND METHOD OF MONITORING PARTICULATE MATERIAL IN A FLUID



(57) Abstract

Apparatus for monitoring particulate material in a fluid comprising a passageway (17), through which fluid to be monitored is passed, at least a portion (24) of the boundary of the passageway (17) being translucent to enable radiation to pass through that portion (24). A camera (40) is arranged to receive such radiation and is constructed to generate electrical signals representative of the images it receives. Image analysis means (57) are connected to receive those electrical signals and to provide data from them relating to the particulate material contained within the fluid.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Republic of Macedonia	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MW	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MX	Malawi	US	United States of America
CA	Canada	IT	Italy	NE	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's	PL	New Zealand		
CM	Cameroon		Republic of Korea	PT	Poland		
CN	China	KR	Republic of Korea	RO	Portugal		
CU	Cuba	KZ	Kazakhstan	RU	Romania		
CZ	Czech Republic	LC	Saint Lucia	SD	Russian Federation		
DE	Germany	LI	Liechtenstein	SE	Sudan		
DK	Denmark	LK	Sri Lanka	SG	Sweden		
EE	Estonia	LR	Liberia		Singapore		

-2-

to receive such radiation and which is constructed to generate electrical signals representative of the images it receives, and image analysis means connected to receive those electrical signals and to provide data from 5 them relating to the particulate material contained within the fluid.

The camera may be a stills camera triggered to operate by the image analysis means.

Preferably, however, the camera is a video camera, 10 and the image analysis means comprises a frame grabber connected to the video camera to isolate a frame from the signals generated by the video camera and an image analyser connected to receive signals of successive frames from the frame grabber so as to provide data on 15 each successive frame relating to the particulate material contained within the fluid.

Preferably, the said portion is transparent.

The video camera is desirably a Charged Coupled Device (CCD) camera. 20 The radiation may be in the visible range of the electromagnetic spectrum.

In one preferred construction of the apparatus, the image analyser comprises a background memory connected to the frame grabber to store data indicative of the value 25 of background signals of the image seen by the video camera, and subtraction means connected to the background memory and to the frame grabber to subtract the stored values of the background signals from those of the

Apparatus for and method of monitoring particulate material in a fluid

The present invention relates to apparatus for monitoring particulate material in a fluid, as well as to a method of monitoring particulate material in a fluid, whether the particulate material comprises a liquid, a solid, or a gas.

One method of doing this, which has already been proposed, involves the scattering of light by such particles and observing the relative strength of light scattered as a function of the angle of scattering. Mie theory is then used to calculate particle size distribution according to the data collected.

One shortcoming of this method is that the theory presumes at least on average that the particles are generally spherical so that it cannot distinguish between spherical particles and non-spherical particles.

It is also necessary to provide more than one sensor viewing a specified target area at respective different

viewing angles.

The present invention seeks to obviate one or more of the foregoing shortcomings.

Accordingly, the present invention is directed to an apparatus for monitoring particulate material in a fluid comprising a passageway, through which fluid to be monitored is passed, at least a portion of the boundary of the passageway being translucent to enable radiation to pass through that portion, a camera, which is arranged

-3-

signals of a subsequent frame isolated by the frame grabber. The benefit of such a construction is that particles which have adhered to the said portion would be disregarded in subsequent image analysis, so that such 5 adhering particles will not skew the results. Preferably, the signals here are those representing a grey scale, more especially ranging in value from zero to 255, in which a zero value can be for the darkest image for a given period and 255 the brightest, or vice versa.

10 In the sense that the signals represent different pixels as different respective values of a grey scale, they are in this specification referred to as analogue signals, even though each value may be coded in eight bits of a byte in what would conventionally be referred 15 to as a digital signal. In the present context, a digital signal is one in which each pixel is represented by one of only two values.

20 Preferably, the image analyser further comprises averaging means to provide the average values of signals from a plurality of successive frames, and hence to provide the said background signals.

25 Advantageously, out-of-focus means are provided to eliminate images of particles which are out of focus when viewed by the camera. This may be achieved by means which check the rate of change in the value of signals received for successive pixels of the image progressing from a position away from the particle to a position well within the boundary of the particle image, and

-4-

eliminating that particle image if the rate of change of the values of the signals never exceeds a predetermined threshold value.

To eliminate skewing from half-portions of particle images at the very edges of the field of view, any particle image which is closer than a predetermined distance to the edge of the field of view may be eliminated by edge-of-field elimination means.

Preferably, the image analyser is further provided with an analogue-to-digital converter in which any pixel having a value beyond a predetermined threshold value in the analogue input is accorded one of two values in the digital output, and any pixel having a value equal to or below the said threshold value is accorded the other of the two values in the digital output. This provides the advantage that subsequent analysis of the data may be effected simply by counting successive adjacent pixels having the said one value in one or more given directions across the field of view. In addition, for example, the total number of pixels of the said one value for a given particle image may be counted to give the total area of the field of view occupied by the particle, or the total number of pixels around the circumference of the particle image may be counted to provide a value for the perimeter of the particle.

Preferably, the fluid is backlit so that the silhouettes of particles are viewed by the video camera.

Preferably, the said portion comprises at least one

... a sapphire window, to reduce the likelihood that the said portion will be scratched and thus rendered less transparent.

The present invention extends to a method of monitoring particulate material in a fluid, in which such fluid is passed through a passageway, at least a portion of the boundary of which is translucent to enable radiation to pass through that portion, viewing the fluid through that portion by means of a camera which is constructed to generate electrical signals representative of the images it receives, and analysing those signals to provide data relating to the particulate material so contained within the fluid.

The fluid analysed may comprise produced water from an oil well, and the image analysis may then be such as to distinguish between particulate material in the form of oil droplets and particulate material which is solid, such as particles of sand.

An example of apparatus for monitoring particulate material in a fluid in accordance with the present invention, as well as a method of monitoring particulate material in a fluid in accordance with the present invention, will now be described with reference to the accompanying drawings, in which:

Figure 1 shows an axial sectional elevational view of the apparatus;

Figure 2 shows an axial sectional view from above of the apparatus shown in Figure 1;

Figure 3 shows a cross-sectional elevational view of the apparatus shown in Figure 1;

Figure 4 shows, on a larger scale, parts of the apparatus shown in Figure 1;

5 Figure 5 shows a block circuit diagram of circuitry connected to a camera of the apparatus shown in Figure 1;

Figure 6 shows a flow chart of successive steps executed by computer program loaded in the 10 circuitry shown in Figure 5; and

Figure 7 shows possible options for the operation of the said foregoing computer program.

The apparatus shown in Figures 1 and 2 comprises a housing 10, which is substantially 450mm long by 150mm 15 wide by 150mm high and which has lower and upper parts 12 and 14. Extending in an intended vertical direction from above and from below the housing 10 are metal tubular portions 16 defining portions of a passageway 17 through which high pressure water produced from an oil well 20 passes when the apparatus is in use (at pressures of about 30 Bar, possibly up to about 120 Bar, and temperatures of up to about 120°C). In this apparatus, pipe connectors 18 and 20 are provided at the distal ends of the tubular portions 16.

25 The passageway 17 between the two tubular portions 16 extends through a high pressure cell 22 in the interior of the housing 10. At the centre of this cell 22, there are provided respective sapphire windows 24

-7-

and 26 on opposite sides of the passageway. These windows are held by respective clamp units 28 and 30 of the cell 22. Immediately adjacent to one of the sapphire windows 26 is a light emitting diode 32 held in place by an LED mounting bracket 34. A microscope unit 36 is arranged to view the interior of the passageway through the other sapphire window 24 so that the passageway interior is backlit by the diode 32. The microscope 36 comprises a lens 38 and a CCD video camera 40 mounted on a bracket 41 and spaced from the lens 38 by an aluminium alloy tube 42, the camera 40 being directed to view the interior of the passageway 17 via the lens 38.

Figure 4 shows the sapphire windows 24 and 26 in greater detail. Thus, the sapphire windows 24 and 26 are held in place in their clamp units 28 and 30 by clamps 44 and 46, respectively. The windows 24 and 26 comprise sapphire plates which are parallel to one another but spaced apart, the space between them constituting part of the passageway 17. The internal sides of the sapphire windows 24 and 26 are provided with wash fluid inlets 48 and 50 which open on to the respective windows 24 and 26 via fanned jets 52 and 54, respectively. These can be connected to a reservoir of cleaning solution (not shown) or to a process line which carries the fluid to be monitored, and serve to dislodge any build-up of dirt on the windows 24 and 26.

The circuitry used in conjunction with the camera 40 is shown in Figure 5. It comprises a frame grabber 56

provided as a frame grabber 56 located within a computer 57. The frame grabber 56 is connected to receive video signals from the camera 40 and to isolate successive frames from those signals. The circuitry 5 further comprises particle recognition and validation means 58 (including a background memory 59) connected to receive signals from the frame grabber and to eliminate from the picture images of particles which are to be selectively excluded from the data; an analogue-to-digital converter 60 connected to receive signals from the recognition and validation means 58, a particle analyser 62 connected to receive signals from the converter 60 and a data recorder 64 connected to receive signals from the particle analyser 62. The recorded data 15 can be viewed on a screen or a printer as a data output 66 of the circuitry and a user interface 68 is connected to the frame grabber 56, the particle recognition and validation means 58, the particle analyser recorder 62, the data recorder 64 and the data output 66 to enable a 20 user to customise and make selections for each of the components of the circuitry.

It will be appreciated that the components of the circuitry other than the frame grabber 56 and the data output 66 are preferably parts of a duly programmed 25 microprocessor.

The manner in which the apparatus operates will now be described in detail. In particular, the program executed by the particle recognition and validation means

-9-

58, the analogue-to-digital converter 60, the particle analyser 62 and the data recorder 64 is shown in Figure 6. From the initiation 70 of this program, the background is stored in the background memory 59 and the 15 background subtracted from a subsequent picture received from the frame grabber 56, at step 72 in Figure 6. From this step, pixels having values equal to or below a given threshold value are rejected at step 74, being given the lower of the preset values, and those which are retained 20 are given the higher of the two values. Particles within the field of view are identified at step 76. Its position within the field of view is identified and a 25 check is made as to whether it is within the boundaries of the screen frame selected, at step 78. If the particle is outside the screen frame, it is rejected at step 80. If it is within the frame, a check is made as to whether the edge strength check has been activated by the user at step 86. If it is, a check is made as to whether the edge strength is acceptable at step 88, using 30 analogue signals obtained at step 72. If it is not, then a check is made as to whether filters have been activated by the user, at step 92. If the edge strength routine 35 has not been activated by the user at step 86, then the edge strength test is bypassed. If the filters have been activated by the user at step 92, then a check is made as to whether the filter criteria are met at step 94. This may involve counting the number of pixels lying on a given line across the particle image, or the number

-10-

constituting the whole area of the particle image, or the number across the outside of the particle image to give its perimeter, and ascertaining whether the count lies above and/or below a preset threshold. Other filters may 5 be made to ascertain whether one or more of the following parameters meet preselected criteria: centre of gravity, average feret diameter, aspect ratio (minimum to maximum feret diameter ratio), shape factor, specific length and/or width, estimated volume, area fraction (the area 10 of the particle image as a fraction of the area of the field of view), Martin's Radii (radii from the centre of gravity), average Martin's Radius, fractal number (by comparing perimeters at successive decreasing sizes of pixel steps), concentration, curvature. If the filter 15 criteria are not met at step 94, a further check is made as to whether this requires the particle to be excluded at step 96. If it does, the particle is rejected at step 98. If it does not, then the database is updated at step 100, by incrementing the relevant population count, as 20 well as adding to the database all the measured parameters for that particle. This step 100 is also reached from the check on whether the particle meets the filter criteria at step 94 if the result was affirmative, and in addition whether the population meeting such 25 criteria is to be included is checked at step 102. If that population is not to be included, then the particle is again rejected at step 98. Finally, a check is made at step 104 as to whether the database is complete. If it

is not, then the "routine beginning" at step 72 is repeated; otherwise, the procedure is stopped at step 106.

Selections which may be made by the user 88 are shown in Figure 7. These selections are made by a proactive selection routine displayed on the computer screen with the aid of the keyboard and/or mouse. At step 110 in this routine, a selection is made as to which database compiling mode is desired. Whether it is by the total number of particles in the database (selection 112), by time interval (selection 114) or by continuous trend analysis (selection 116). These selections require no further input from the user, being respectively the total number (for example 30,000) of particles required for the database (input 118), the time for collecting the database and the time for resting (input 120) (for example twenty minutes, or twenty minutes of each hour) and the database size required and collection frequency (for example once every 190 minutes) (input 122). Regardless of which selections were made initially, the parameters to be recorded, for example, size, area or "shape" factor are entered at step 124, and filter parameters, such as the upper and lower limits, the reduction criteria and the sub-populations desired are selected at step 126. For selections 112 and 114, a further selection is made regarding the manner in which the data is to be represented, whether by tables, histograms or integral curves at step 128. For an

-12-

... initial selection 116, a further selection of the method of trend analysis and pre-set alarm limits is made at step 130. Regardless of the initial selection which was made, an option may be made at step 132 to print out data automatically of the required parameters or populations if that is relevant. At step 134, all required measuring parameters, such as a small particle filter made at step 82 in Figure 6, the threshold value for step 74, and the edge strength acceptance parameter for step 88, are entered, and lastly, the step for commencement of the monitoring process is initiated at step 136.

It will be appreciated that the function of the high pressure cell is to allow the camera 40 to see into the fluid to be monitored, that is, also commonly referred to as, the process stream, without changing the conditions within the process stream (such as its pressure and temperature).

The CCD camera 40 may be one which is similar to the type used in security surveillance systems. The lens 38 may be selectable from any one of a choice of magnifying objective lenses, so it is able to see very small particles within the process stream. For example, the set of lenses available may be as is common in microscopy, with magnifications of x 4, x 7 and x 10. As a result, the apparatus may be used to measure particles ranging in size from one micron (1 x 10⁻⁶m) to a few millimetres. With the illustrated apparatus, it is possible to

-13-

carry out discrete sampling and perhaps use this data to monitor a particular batch of material or the effect of changing a particular process condition. By making periodic measurements it is possible to generate quality control information related to production periods. By trend (or continuous) measurement both the actual state of a process can be monitored and process upsets can be forecast, saving time and money.

The illustrated apparatus does not involve any assumption that it will be presented with a homogenous sample and it is possible to divide the particulates within a process stream into sub-populations, that may or may not have particular relevance to the production process. Up to eight sub-populations can be measured simultaneously, so that it would be possible, for example, to measure and monitor the concentration of both sand particles and oil droplets in the produced water of an oil well.

In regard to the last mentioned application, when oil is pumped out of the ground, it is a mixture of oil, water, solids and gases. It is relatively straightforward to remove the gases and the greater proportion of the oil from this mixture. What remains is mostly water with oil droplets and solids.

There are a number of different methods available to an oil producer to further extract enough of the oil from this mixture to make either re-injection or dumping viable. Some of these methods involve using chemicals to help the oil coalesce; these are expensive and

-14-

hazardous. Some methods use mechanical separation techniques; these are subject to efficiency variations with, for example pump speeds, and can be damaged by high concentrations of solids. There are other techniques, 5 nearly all of which benefit from monitoring oil droplet size, solids size and concentrations of both.

In most of these examples, it is essential to monitor oil droplet size and concentration, for example, in order to use the absolute minimum quantity of chemicals, or to 10 ensure hydrocyclones and centrifuges are operating at optimum speed. Often it is important to monitor the size and concentration of solids (sands) at the same time, to prevent blocking and/or abrasion, for example.

By using the filters within as described herein, the 15 illustrated apparatus can simply differentiate between oil droplets and solids within a single sample. Using the trend analysis routine also allows both monitoring of current conditions within the process and preventative measures to be taken if a process upset is predicted. 20 Trend analysis also allows operators to monitor what effect a change in process conditions has.

Another possible use of the illustrated apparatus is in relation to high quality paper stocks (for example for bank notes). These may be made from cotton fibres, and 25 may contain other materials such as fillers and pigments.

The length of the fibres used in the stock determine the strength and quality of the paper. The amount of filler and pigment affect the cost of production and

paper 'colour'. There is a 'further' factor, fibrillation (how many side branches a fibre has and how long these are), that affects the paper. Fibres with a great degree of fibrillation become easily knotted and lumpy, whereas fibres with a small degree of fibrillation may not form a paper strong enough to use. Both the type of fibre used and the way the fibre is treated affect the degree of fibrillation.

By using appropriate filters within the illustrated apparatus, the latter can simply differentiate between fibres and fillers, or between liquid or solid particles within a single sample. Furthermore, by use of fractal analysis, the degree of fibrillation of the fibres can be determined. For example, if a liquid stream is to be analysed that carries an emulsion and some solid particles, it would be possible to determine the size distribution for each of these populations individually. To effect this, a filter of shape factor is selected and whether a particle is liquid emulsion or solid can be determined by its shape factor. Liquid emulsions are spherical and have a shape factor approaching one, therefore a filter of shape factor 0.85 can be selected so that all particles which exceed 0.85 are recorded to the liquid database and particles below 0.85 are recorded to the solid database.

Users may filter the databases as 'above' using the measured parameters. The software allows for the use of

two filters combined. For example, if filter one AND filter two are passed, then the count is passed to population "x" in the database. If NEITHER filter one NOR filter two are passed, then the count is passed to population "y". If filter one but not filter two is passed, then the count is passed to population "z". Each outcome is stored to a database or discarded from the analysis according to user choice.

Regardless of the application for which the illustrated apparatus is being used, the trend analysis routine also allows both monitoring of current conditions within the process and preventative measures to be taken if a process upset is predicted. Trend analysis also allows operators to monitor what effect a change in process or stock conditions has. Thus, by gathering data for a particular function over a period of time, it is possible to predict if that function is going to increase or decrease over time. It is also possible to predict at what point the function might fall outside preset limits.

For example, by monitoring particle size in a process for a period during satisfactory operation, it is possible to predict if that process may be tending to increased particle sizes and the point at which the particle size will be too large for satisfactory operation. A user message may be printed or displayed by the computer at this stage. Such a prediction can be made over the next two measuring periods at any given stage, and when there are only few points plotted, it can be made by a least

squares line of best fit. When a larger number of data points are available, prediction could be by monitoring the rate of change of gradient of a linear regression.

More than one parameter may be monitored in this way 5 at the same time, for one or more populations or sub-populations of particle meeting respective different criteria.

Any picture seen by the camera may of course be saved by means of the computer.

10 Thus, the illustrated apparatus provides a flexible instrument package, which can cater for any selected one 15 or a large number of applications in a wide range of 20 industrial processes, for example, in the field of

25 A different light source may be used instead of the diode 52.

Control means may be provided to control the 30 intensity of a light source.

A calibration factor is provided to enable pixel 35 size to be converted to microns dependent on the magnification of the lens in use.

40 Visual prompt type warnings are given if the user attempts to discard measured data without saving it.

45 Visual prompt type warnings are also given if the user attempts to set filters or database parameters that 50 are impossible, for example if a particle is required to have an aspect ratio >0.7 and at the same time an aspect ratio <0.7, or if a command is given to collect data for the first twenty minutes of each fifteen period.

The illustrated apparatus can make available results in relation to an individual particle, an individual image, a database of particles, and trend statistics.

Consequently, the first and most important task is to identify the main components of the system and to understand their interactions.

Claims:

1. Apparatus for monitoring particulate material in a fluid comprising a passageway, through which fluid to be monitored is passed, at least a portion of the boundary of the passageway being translucent to enable radiation to pass through that portion, a camera, which is arranged to receive such radiation and which is constructed to generate electrical signals representative of the images it receives, and image analysis means connected to receive those electrical signals and to provide data from them relating to the particulate material contained within the fluid.
2. Apparatus according to claim 1, in which the said portion is transparent.
3. Apparatus according to claim 1 or claim 2, in which the camera is a stills camera triggered to operate by the image analysis means.
4. Apparatus according to claim 1 or claim 2, in which the camera is a video camera, and the image analysis means comprises a frame grabber connected to the video camera to isolate a frame from the signals generated by the video camera and an image analyser connected to receive signals of successive frames from the frame grabber so as to provide data on each successive frame relating to the particulate material contained within the fluid.
5. Apparatus according to claim 4, in which the video camera is a Charged Coupled Device (CCD) camera.

-20-

6. Apparatus according to any preceding claim, in which the radiation is in the visible range of the electromagnetic spectrum.

7. Apparatus according to any preceding claim, in which the image analyser comprises a background memory connected to the frame grabber to store data indicative of the value of background signals of the image seen by the video camera, and subtraction means connected to the background memory and to the frame grabber to subtract the stored values of the background signals from those of the signals of a subsequent frame isolated by the frame grabber. The benefit of such a construction is that particles which have adhered to the said portion would be disregarded in subsequent image analysis, so that such adhering particles will not skew the results. Preferably, the signals here are those representing a grey scale, more especially ranging in value from zero to 255, in which a zero value can be for the darkest image for a given period and 255 the brightest, or vice versa.

8. Apparatus according to claim 7, in which the image analyser further comprises averaging means to provide the average values of signals from a plurality of successive frames, and hence to provide the said background signals.

9. Apparatus according to claim 7 or claim 8, in which the image analyser is further provided with an analogue-to-digital converter in which any pixel having a value beyond a predetermined threshold value in the analogue input is accorded one of two values in the digital

output,' and 'any pixel having a value equal to or below the said threshold value is accorded the other of the two values in the digital output.'

10. 'Apparatus according to any preceding claim, in which out-of-focus elimination means are provided to eliminate images of particles which are out of focus when viewed by the camera.'

11. 'Apparatus according to claim 10, in which the out-of-focus elimination means check the rate of change in the value of signals received for successive pixels of the image progressing from a position away from the particle to a position well within the boundary of the particle image, and eliminate that particle image if the rate of change of the values of the signals never exceeds a predetermined threshold value.'

12. 'Apparatus according to any preceding claim, comprising edge-of-field elimination means to eliminate any particle image which is closer than a predetermined distance to the edge of the field of view.'

13. 'Apparatus according to any preceding claim, in which the fluid is backlit so that the silhouettes of particles are viewed.'

14. 'Apparatus according to any preceding claim, in which the said portion comprises at least one sapphire window, to reduce the likelihood that the said portion will be scratched and thus rendered less transparent.'

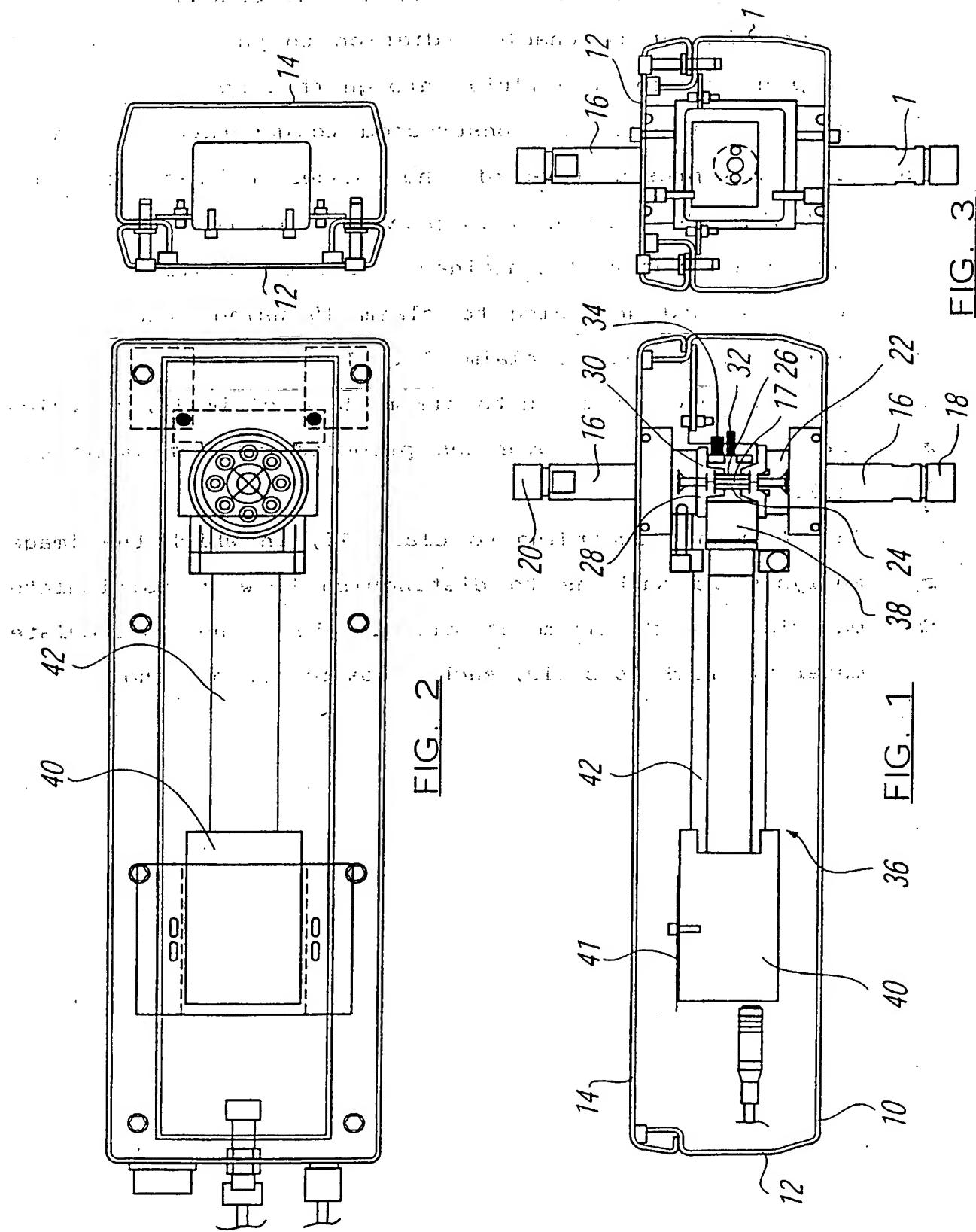
15. 'A method of monitoring particulate material in a fluid, in which such fluid is passed through a

-22-

passageway, at least a portion of the boundary of which is translucent to enable radiation to pass through that portion, viewing the fluid through that portion by means of a camera which is constructed to generate electrical signals representative of the images it receives, and analysing those signals to provide data relating to the particulate material contained within the fluid.

- 15 16. A method according to claim 15 using apparatus as claimed in any one of claims 1 to 14.
- 10 17. A method according to claim 15 or claim 16, in which the fluid analysed comprises produced water from an oil well.
18. A method according to claim 17, in which the image analysis is such as to distinguish between particulate material in the form of oil droplets and particulate material which is solid, such as particles of sand.

1/5



SUBSTITUTE SHEET (RULE 26)

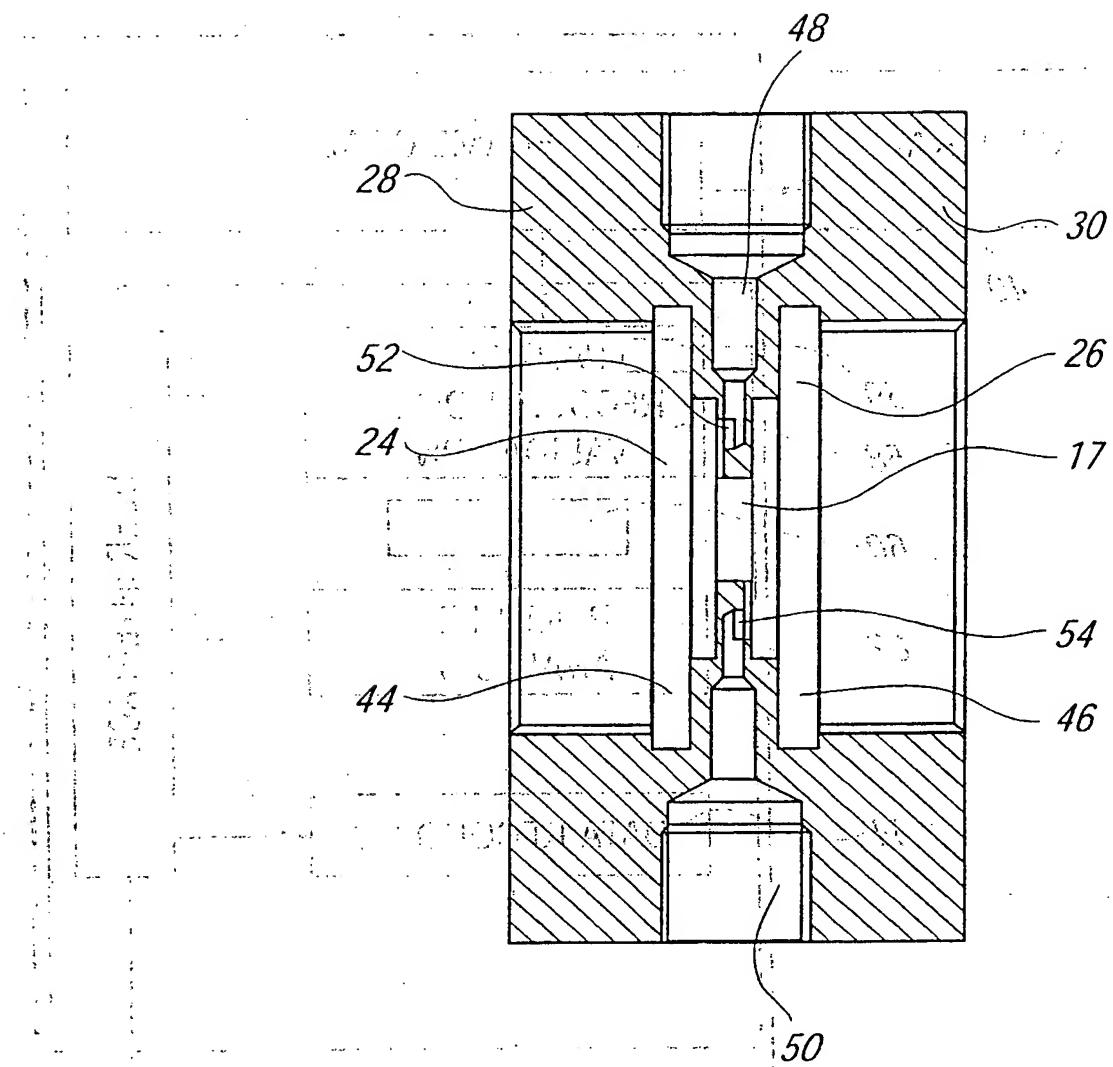


FIG. 4

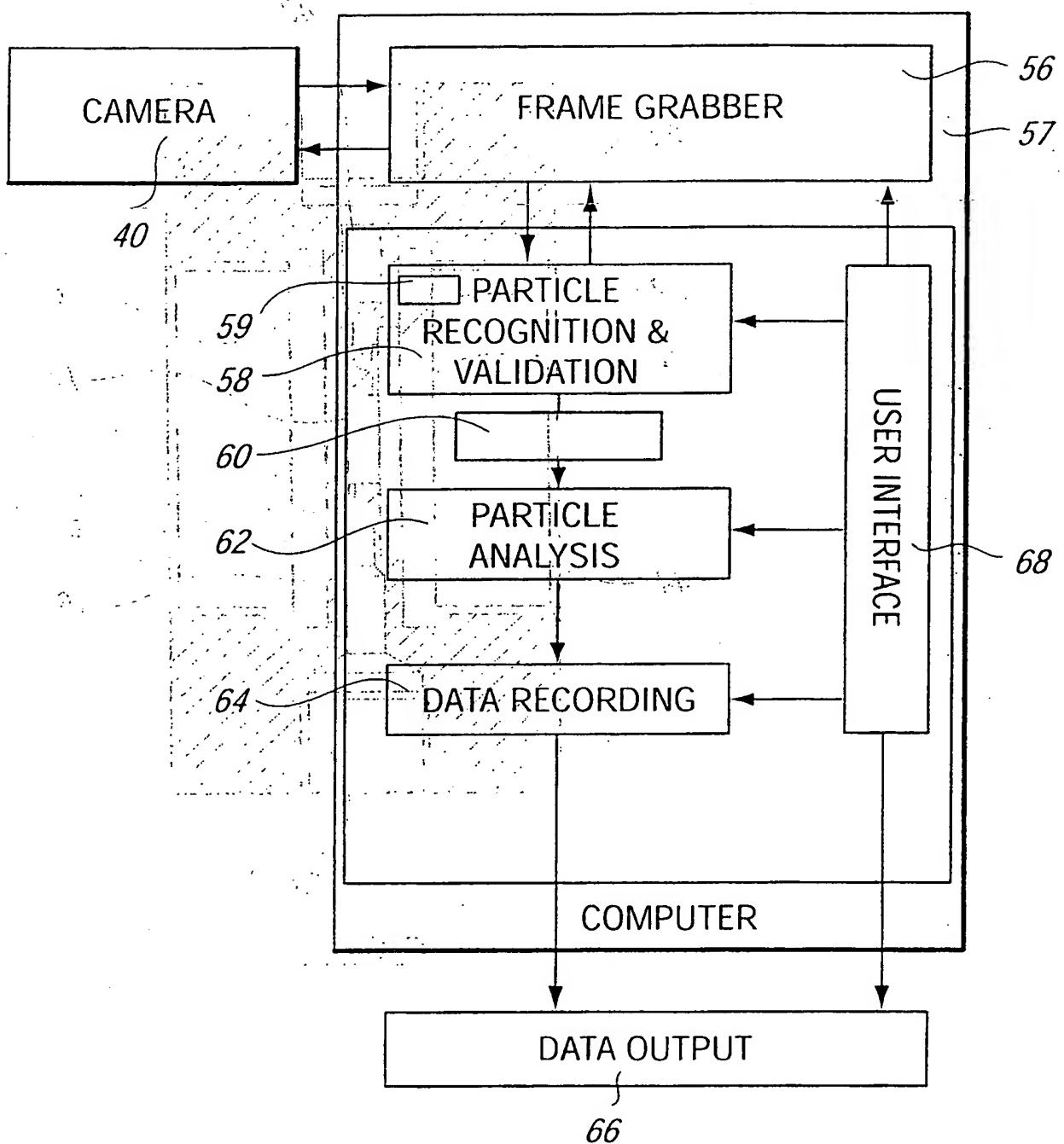


FIG. 5

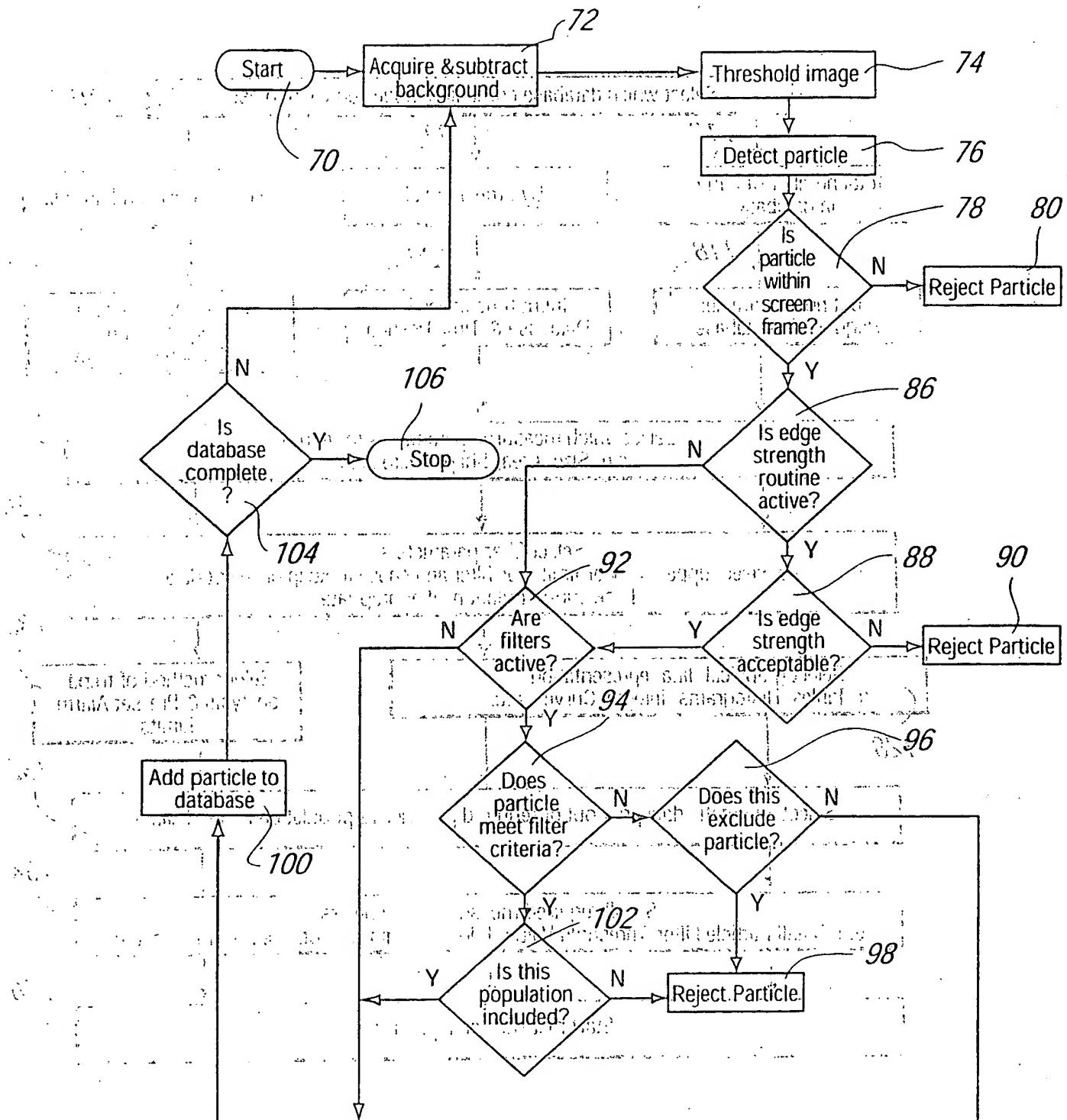


FIG. 6

SUBSTITUTE SHEET (RULE 26)

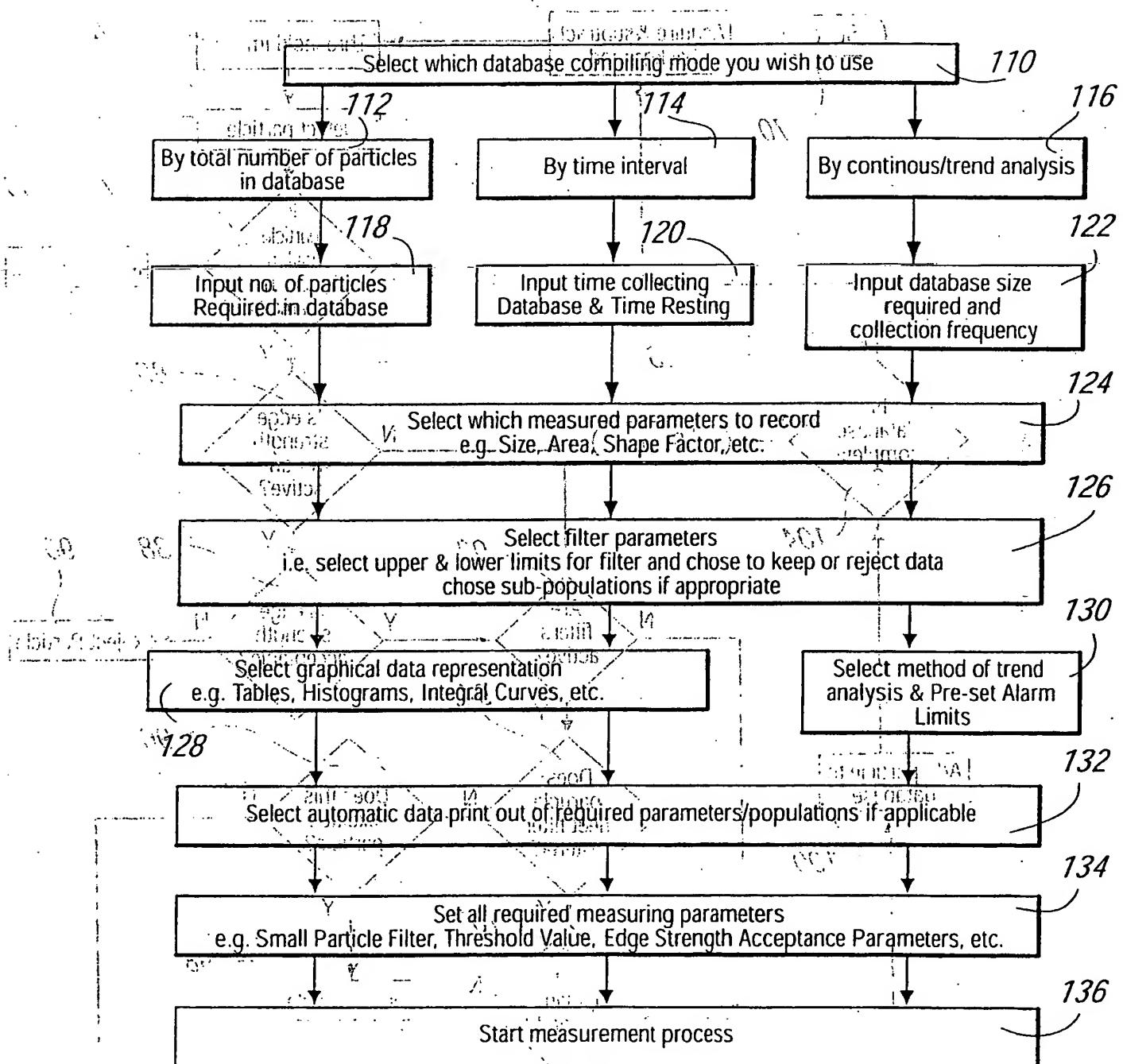


FIG. 7

1920-1921
1921-1922
1922-1923
1923-1924
1924-1925
1925-1926
1926-1927
1927-1928
1928-1929
1929-1930
1930-1931
1931-1932
1932-1933
1933-1934
1934-1935
1935-1936
1936-1937
1937-1938
1938-1939
1939-1940
1940-1941
1941-1942
1942-1943
1943-1944
1944-1945
1945-1946
1946-1947
1947-1948
1948-1949
1949-1950
1950-1951
1951-1952
1952-1953
1953-1954
1954-1955
1955-1956
1956-1957
1957-1958
1958-1959
1959-1960
1960-1961
1961-1962
1962-1963
1963-1964
1964-1965
1965-1966
1966-1967
1967-1968
1968-1969
1969-1970
1970-1971
1971-1972
1972-1973
1973-1974
1974-1975
1975-1976
1976-1977
1977-1978
1978-1979
1979-1980
1980-1981
1981-1982
1982-1983
1983-1984
1984-1985
1985-1986
1986-1987
1987-1988
1988-1989
1989-1990
1990-1991
1991-1992
1992-1993
1993-1994
1994-1995
1995-1996
1996-1997
1997-1998
1998-1999
1999-2000
2000-2001
2001-2002
2002-2003
2003-2004
2004-2005
2005-2006
2006-2007
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014
2014-2015
2015-2016
2016-2017
2017-2018
2018-2019
2019-2020
2020-2021
2021-2022
2022-2023
2023-2024
2024-2025
2025-2026
2026-2027
2027-2028
2028-2029
2029-2030
2030-2031
2031-2032
2032-2033
2033-2034
2034-2035
2035-2036
2036-2037
2037-2038
2038-2039
2039-2040
2040-2041
2041-2042
2042-2043
2043-2044
2044-2045
2045-2046
2046-2047
2047-2048
2048-2049
2049-2050
2050-2051
2051-2052
2052-2053
2053-2054
2054-2055
2055-2056
2056-2057
2057-2058
2058-2059
2059-2060
2060-2061
2061-2062
2062-2063
2063-2064
2064-2065
2065-2066
2066-2067
2067-2068
2068-2069
2069-2070
2070-2071
2071-2072
2072-2073
2073-2074
2074-2075
2075-2076
2076-2077
2077-2078
2078-2079
2079-2080
2080-2081
2081-2082
2082-2083
2083-2084
2084-2085
2085-2086
2086-2087
2087-2088
2088-2089
2089-2090
2090-2091
2091-2092
2092-2093
2093-2094
2094-2095
2095-2096
2096-2097
2097-2098
2098-2099
2099-20100
20100-20101
20101-20102
20102-20103
20103-20104
20104-20105
20105-20106
20106-20107
20107-20108
20108-20109
20109-20110
20110-20111
20111-20112
20112-20113
20113-20114
20114-20115
20115-20116
20116-20117
20117-20118
20118-20119
20119-20120
20120-20121
20121-20122
20122-20123
20123-20124
20124-20125
20125-20126
20126-20127
20127-20128
20128-20129
20129-20130
20130-20131
20131-20132
20132-20133
20133-20134
20134-20135
20135-20136
20136-20137
20137-20138
20138-20139
20139-20140
20140-20141
20141-20142
20142-20143
20143-20144
20144-20145
20145-20146
20146-20147
20147-20148
20148-20149
20149-20150
20150-20151
20151-20152
20152-20153
20153-20154
20154-20155
20155-20156
20156-20157
20157-20158
20158-20159
20159-20160
20160-20161
20161-20162
20162-20163
20163-20164
20164-20165
20165-20166
20166-20167
20167-20168
20168-20169
20169-20170
20170-20171
20171-20172
20172-20173
20173-20174
20174-20175
20175-20176
20176-20177
20177-20178
20178-20179
20179-20180
20180-20181
20181-20182
20182-20183
20183-20184
20184-20185
20185-20186
20186-20187
20187-20188
20188-20189
20189-20190
20190-20191
20191-20192
20192-20193
20193-20194
20194-20195
20195-20196
20196-20197
20197-20198
20198-20199
20199-20200
20200-20201
20201-20202
20202-20203
20203-20204
20204-20205
20205-20206
20206-20207
20207-20208
20208-20209
20209-20210
20210-20211
20211-20212
20212-20213
20213-20214
20214-20215
20215-20216
20216-20217
20217-20218
20218-20219
20219-20220
20220-20221
20221-20222
20222-20223
20223-20224
20224-20225
20225-20226
20226-20227
20227-20228
20228-20229
20229-20230
20230-20231
20231-20232
20232-20233
20233-20234
20234-20235
20235-20236
20236-20237
20237-20238
20238-20239
20239-20240
20240-20241
20241-20242
20242-20243
20243-20244
20244-20245
20245-20246
20246-20247
20247-20248
20248-20249
20249-20250
20250-20251
20251-20252
20252-20253
20253-20254
20254-20255
20255-20256
20256-20257
20257-20258
20258-20259
20259-20260
20260-20261
20261-20262
20262-20263
20263-20264
20264-20265
20265-20266
20266-20267
20267-20268
20268-20269
20269-20270
20270-20271
20271-20272
20272-20273
20273-20274
20274-20275
20275-20276
20276-20277
20277-20278
20278-20279
20279-20280
20280-20281
20281-20282
20282-20283
20283-20284
20284-20285
20285-20286
20286-20287
20287-20288
20288-20289
20289-20290
20290-20291
20291-20292
20292-20293
20293-20294
20294-20295
20295-20296
20296-20297
20297-20298
20298-20299
20299-202100
202100-202101
202101-202102
202102-202103
202103-202104
202104-202105
202105-202106
202106-202107
202107-202108
202108-202109
202109-202110
202110-202111
202111-202112
202112-202113
202113-202114
202114-202115
202115-202116
202116-202117
202117-202118
202118-202119
202119-202120
202120-202121
202121-202122
202122-202123
202123-202124
202124-202125
202125-202126
202126-202127
202127-202128
202128-202129
202129-202130
202130-202131
202131-202132
202132-202133
202133-202134
202134-202135
202135-202136
202136-202137
202137-202138
202138-202139
202139-202140
202140-202141
202141-202142
202142-202143
202143-202144
202144-202145
202145-202146
202146-202147
202147-202148
202148-202149
202149-202150
202150-202151
202151-202152
202152-202153
202153-202154
202154-202155
202155-202156
202156-202157
202157-202158
202158-202159
202159-202160
202160-202161
202161-202162
202162-202163
202163-202164
202164-202165
202165-202166
202166-202167
202167-202168
202168-202169
202169-202170
202170-202171
202171-202172
202172-202173
202173-202174
202174-202175
202175-202176
202176-202177
202177-202178
202178-202179
202179-202180
202180-202181
202181-202182
202182-202183
202183-202184
202184-202185
202185-202186
202186-202187
202187-202188
202188-202189
202189-202190
202190-202191
202191-202192
202192-202193
202193-202194
202194-202195
202195-202196
202196-202197
202197-202198
202198-202199
202199-202200
202200-202201
202201-202202
202202-202203
202203-202204
202204-202205
202205-202206
202206-202207
202207-202208
202208-202209
202209-202210
202210-202211
202211-202212
202212-202213
202213-202214
202214-202215
202215-202216
202216-202217
202217-202218
202218-202219
202219-202220
202220-202221
202221-202222
202222-202223
202223-202224
202224-202225
202225-202226
202226-202227
202227-202228
202228-202229
202229-202230
202230-202231
202231-202232
202232-202233
202233-202234
202234-202235
202235-202236
202236-202237
202237-202238
202238-202239
202239-202240
202240-202241
202241-202242
202242-202243
202243-202244
202244-202245
202245-202246
202246-202247
202247-202248
202248-202249
202249-202250
202250-202251
202251-202252
202252-202253
202253-202254
202254-202255
202255-202256
202256-202257
202257-202258
202258-202259
202259-202260
202260-202261
202261-202262
202262-202263
202263-202264
202264-202265
202265-202266
202266-202267
202267-202268
202268-202269
202269-202270
202270-202271
202271-202272
202272-202273
202273-202274
202274-202275
202275-202276
202276-202277
202277-202278
202278-202279
202279-202280
202280-202281
202281-202282
202282-202283
202283-202284
202284-202285
202285-202286
202286-202287
202287-202288
202288-202289
202289-202290
202290-202291
202291-202292
202292-202293
202293-202294
202294-202295
202295-202296
202296-202297
202297-202298
202298-202299
202299-202300
202300-202301
202301-202302
202302-202303
202303-202304
202304-202305
202305-202306
202306-202307
202307-202308
202308-202309
202309-202310
202310-202311
202311-202312
202312-202313
202313-202314
202314-202315
202315-202316
202316-202317
202317-202318
202318-202319
202319-202320
202320-202321
202321-202322
202322-202323
202323-202324
202324-202325
202325-202326
202326-202327
202327-202328
202328-202329
202329-202330
202330-202331
202331-202332
202332-202333
202333-202334
202334-202335
202335-202336
202336-202337
202337-202338
202338-202339
202339-202340
202340-202341
202341-202342
202342-202343
202343-202344
202344-202345
202345-202346
202346-202347
202347-202348
202348-202349
202349-202350
202350-202351
202351-202352
202352-202353
202353-202354
202354-202355
202355-202356
202356-202357
202357-202358
202358-202359
202359-202360
202360-202361
202361-202362
202362-202363
202363-202364
202364-202365
202365-202366
202366-202367
202367-202368
202368-202369
202369-202370
202370-202371
202371-202372
202372-202373
202373-202374
202374-202375
202375-202376
202376-202377
202377-202378
202378-202379
202379-202380
202380-202381
202381-202382
202382-202383
202383-202384
202384-202385
202385-202386
202386-202387
202387-202388
202388-202389
202389-202390
202390-202391
202391-202392
202392-202393
202393-202394
202394-202395
202395-202396
202396-202397
202397-202398
202398-202399
202399-202400
202400-202401
202401-202402
202402-202403
202403-202404
202404-202405
202405-202406
202406-202407
202407-202408
202408-202409
202409-202410
202410-202411
202411-202412
202412-202413
202413-202414
202414-202415
202415-202416
202416-202417
202417-202418
202418-202419
202419-202420
202420-202421
202421-202422
202422-202423
202423-202424
202424-202425
202425-202426
202426-202427
202427-202428
202428-202429
202429-202430
202430-202431
202431-202432
202432-202433
202433-202434
202434-202435
202435-202436
202436-202437
202437-202438
202438-202439
202439-202440
202440-202441
202441-202442
202442-202443
202443-202444
202444-202445
202445-202446
202446-202447
202447-202448
202448-202449
202449-202450
202450-202451
202451-202452
202452-202453
202453-202454
202454-202455
202455-202456
202456-202457
202457-202458
202458-202459
202459-202460
202460-202461
202461-202462
202462-202463
202463-202464
202464-202465
202465-202466
202466-202467
202467-202468
202468-202469
202469-202470
202470-202471
202471-202472
202472-202473
202473-202474
202474-202475
202475-202476
202476-202477
202477-202478
202478-202479
202479-202480
202480-202481
202481-202482
202482-202483
202483-202484
202484-202485
202485-202486
202486-202487
202487-202488
202488-202489
202489-202490
202490-202491
202491-202492
202492-202493
202493-202494
202494-202495
202495-202496
202496-202497
202497-202498
202498-202499
202499-202500
202500-202501
202501-202502
202502-202503
202503-202504
202504-202505
202505-202506
202506-202507
202507-202508
202508-202509
202509-202510
202510-202511
202511-202512
202512-202513
202513-202514
202514-202515
202515-202516
202516-202517
202517-202518
202518-202519
202519-202520
202520-202521
202521-202522
202522-202523
202523-202524
202524-202525
202525-202526
202526-202527
202527-202528
202528-202529
202529-202530
202530-202531
202531-202532
202532-202533
202533-202534
202534-202535
202535-202536
202536-202537
202537-202538
202538-202539
202539-202540
202540-202541
202541-202542
202542-202543
202543-202544
202544-202545
202545-202546
202546-202547
202547-202548
202548-202549
202549-202550
202550-202551
202551-202552
202552-202553
202553-202554
202554-202555
202555-202556
202556-202557
202557-202558
202558-202559
202559-202560
202560-202561
202561-202562
202562-202563
202563-202564
202564-202565
202565-202566
202566-202567
202567-202568
202568-202569
202569-202570
202570-202571
202571-202572
202572-202573
202573-202574
202574-202575
202575-202576
202576-202577
202577-202578
202578-202579
202579-202580
202580-202581
202581-202582
202582-202583
202583-202584
202584-202585
202585-202586
202586-202587
202587-202588
202588-202589
202589-202590
202590-202591
202591-202592
202592-202593
202593-202594
202594-202595
202595-202596
202596-202597
202597-202598
202598-202599
202599-202600
202600-202601
202601-202602
202602-202603
202603-202604
202604-202605
202605-202606
202606-202607
202607-202608
202608-202609
202609-202610
202610-202611
202611-202612
202612-202613
202613-202614
202614-202615
202615-202616
202616-202617
202617-202618
20261

FIGURE 1. PRELIMINARY SKETCH OF THE CLOUDS
IN THE SKY.

ALATOSIS

Академия
наука
и техника
СССР
и Академия
наука
и техника
РСФСР
и Академия
наука
и техника
УССР

1939

卷之三